

# Solid Oxide Fuel Cell Development for Auxiliary Power in Heavy Duty Vehicle Applications

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**Delphi**

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Sponsor: U.S. DOE – Hydrogen, Fuel Cells and Infrastructure Technologies  
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Partners: PACCAR, Volvo Trucks North America (VTNA), & Electricore

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◆ Program: Solid Oxide Fuel Cell (SOFC) for Auxiliary Power in Heavy Duty Vehicle Applications

– **Project ID:** DE-FC36-04GO14319

– **Funding:** \$4,700,000

– **Duration:** 48 Months – Project Start Date: September 2004

– **Industry Principal Investigator:**

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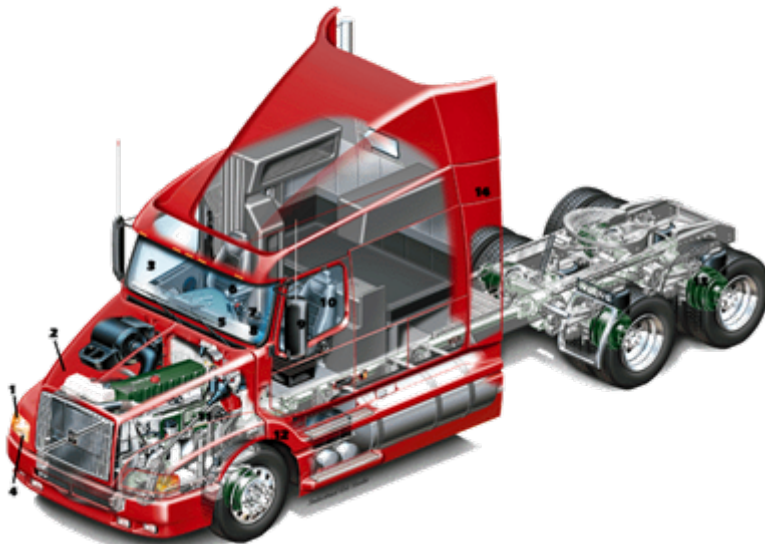
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- ◆ Delphi has teamed with OEM's PACCAR Incorporated and Volvo Trucks North America (VTNA) to define system level requirements for a Fuel Cell (SOFC) based Auxiliary Power Unit (APU) for the commercial trucking industry. Delphi has enlisted Electricore to provide administrative assistance

## VOLVO



**Volvo Trucks North America (VTNA),  
Greensboro, NC**

## PACCAR

 **KENWORTH**







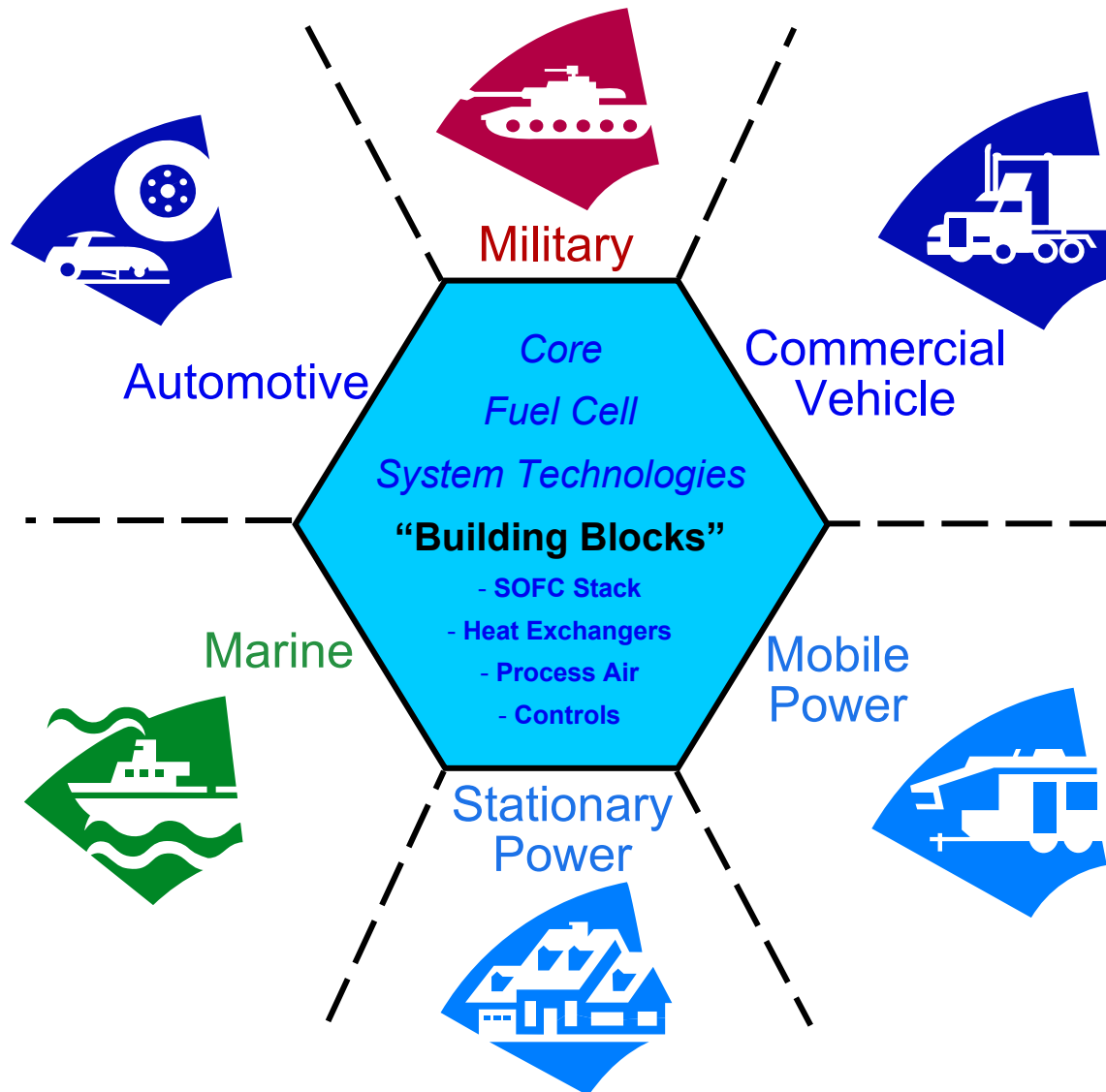
**Foden Trucks**  
A Division of PACCAR U.S. Inc.



**PACCAR, Bellevue, WA**

# Overview of SOFC Technology Development Program

**Development Strategy Overview:** Development of core sub-system building blocks that will be utilized in systems for each of the target markets



Each application adjusted for:

- Fuel Type
- Electrical Configuration
- Application Environment
- User Interface

## **Program Objectives:**

- ◆ To demonstrate an SOFC APU capable of operating on low sulfur diesel fuel, in a laboratory environment, for the Commercial Trucking Industry.
  - Develop APU system requirements and concepts with major truck OEMs input
  - Design, test and develop the needed subsystems for the selected concept
  - Build and bench demonstrate the selected *diesel fueled* APU system to the DOE

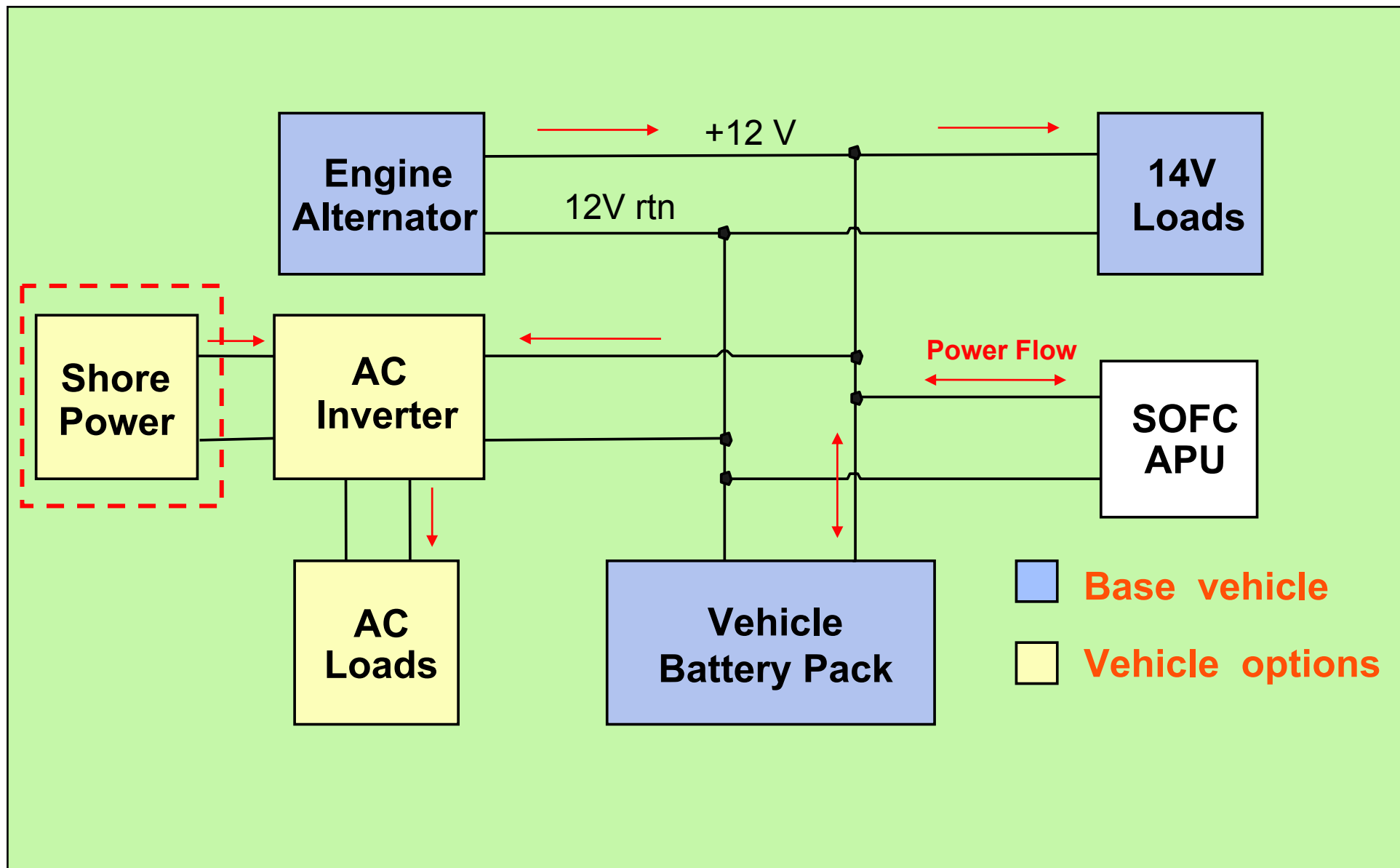
- ◆ Program Technical Approach will involve extracting hydrogen and CO from diesel fuel in a catalytic operation through a Reformer. The output gas from the Reformer will be sent to the fuel cell stack and converted to electrical energy
  
- ◆ The following tasks will be completed during this program
  - *Application Requirements with OEM Input*
  - *APU System Mechanization Concepts*
  - *APU System Requirements, Concept Evaluation, and Selection*
  - *APU System Design and Layout*
  - *Develop Subsystem Requirements and Development plan*
  - *SOFC Hardware Design and Build*
  - *Subsystem Test Fixture Hardware Build*
  - *Subsystem Testing and Development Iterations*
  - *System Module Testing and Development*
  - *Full APU System Testing and Development*
  - *APU System Laboratory Demonstration with Simulated Load Cycles*
  - *Final Report and Presentation*

- ◆ Key areas of collaboration with OEM's PACCAR and VTNA include:
  - Performance and functionality requirements
    - » Power output, durability, response times, expected loads
  - Vehicle operating environment requirements
    - » NVH, temperature, fuel quality, exposure
  - Electrical integration and mounting options for selected vehicles
  - APU physical requirements
    - » Allowable mass, volumes, connection locations
  - Efficiency requirements at peak power and over usage cycles
  - Regulatory issues: exhaust emissions, noise, safety
  - Maintenance and service interval issues





# Vehicle Electrical System Diagram





### **Delphi SOFC APU system architecture is divided into 3-major modules:**

#### ◆ **Hot Zone Module (HZM):**

- SOFC stack module system
- Fuel Reformer system: Diesel fuel processor with anode tailgas recycle operation capacity
- System Heat Exchanger and Component Manifold
- System Tailgas Combustor: Close coupled with reformer (heat transfer and start-up)

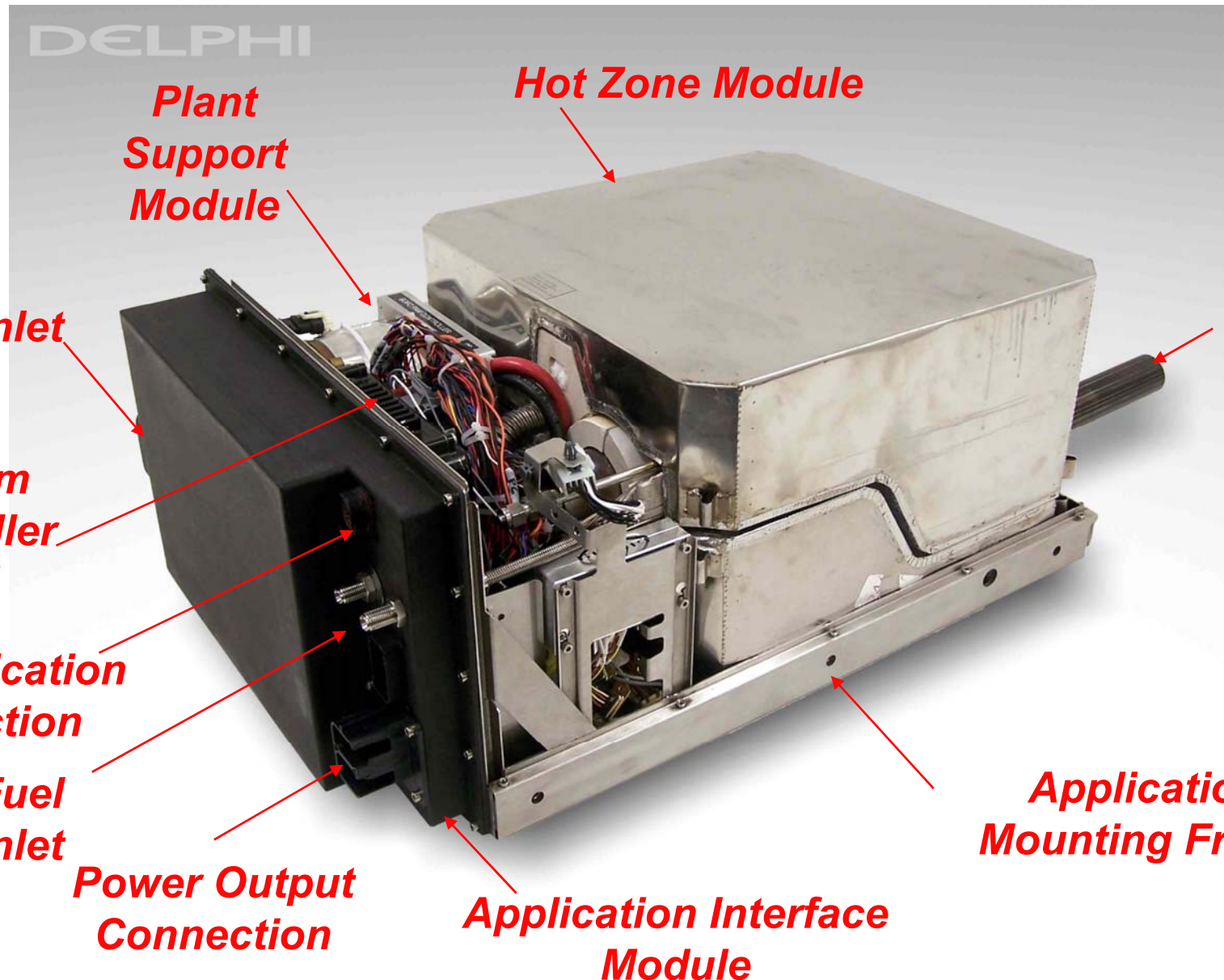
#### ◆ **Plant Support Module (PSM):**

- Balance of Plant: Consists of fuel injector, sensors, pre-heaters, etc.
- Power Conditioner: Converts the stack voltage to a stable DC voltage
- APU System Controller: Controls the SOFC stack and reformer operation
- Anode Recycle System: Added system efficiency and reformer operation benefit

#### ◆ **Application Interface Module (AIM) and Product Enclosure:**

- AIM is closely integrated with PSM but remains customized for power needs
- Product Enclosure solves several issues: Serves as module frame and application cover
- Air filtration (serviceable element)

# SOFC APU Hardware (Generation 3 APU System)



### ◆ **Startup and initialization mode**

- The SOFC accessories will be powered up electrically using the vehicle battery power and bring the SOFC up to operating temperature.

### ◆ **Power mode**

- The SOFC will provide electric power to the vehicle using vehicle diesel fuel to create power.

### ◆ **Standby / Idle mode**

- The SOFC will maintain its temperature within operating levels using diesel fuel and vehicle electric power so that the SOFC will be ready to provide electric power upon request.

### ◆ **Shutdown mode**

- The SOFC will cool down to ambient temperature at a rate determined by the controller.

### Program Accomplishments:

#### Milestone - 1: Requirements Review

- ◆ Collaboration with OEM partners PACCAR and Volvo Truck NA are underway to finalize application requirements for the SOFC APU system
  - Quantifying power, load profile, operating conditions, durability requirements, operator interfaces, safety parameters, volume, mass and mounting requirements for various truck models
  
- ◆ Completion of Milestone –1 (Requirements Review) Meeting with DOE and OEM partners was held on April 14<sup>th</sup>, 2005

## ◆ Remainder of FY 2005

- Development of Vehicle System and APU System Mechanization Concepts
- APU System Requirements
- Milestone #2 Review

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## ◆ FY 2006

- APU Design and Layout
- Subsystem Requirements Document and
- SOFC APU Subsystem Hardware Design and Build

- ◆ In the DOE SOFC APU program hydrogen and CO is extracted from diesel fuel in a catalytic operation in the Reformer. This process makes storage of pure hydrogen unnecessary
  - The Reformate of the Diesel fuel with Partial Oxidation has approximately the following constituents:
    - » *About 25% Hydrogen*
    - » *About 20% CO*
    - » *3% Steam H<sub>2</sub>O*
    - » *Remaining is N<sub>2</sub>, and other species*

- ◆ The most significant hydrogen hazard associated with this project is:
  - During warm-up, at temperatures below 500°C, any hydrogen leaked from the reformer or fuel cell stack could collect in the Hot Zone module. As the temperature rises above 500°C the gasses could combust causing damage
  
- ◆ Our approach to deal with this hazard is:
  - Sealing technologies are being implemented to avoid leakage maximize containment
  - The SOFC APU can be instrumented with H<sub>2</sub> and CO sensors that would detect leakage. The electronic control unit would then take appropriate action to shut down the unit



***Delphi is committed to working with DOE  
to develop the SOFC APU technology  
for a cleaner and more fuel efficient  
commercial truck of the future***



**DELPHI**  
**PACCAR VOLVO**   
**ELECTRICORE**